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Wood Block Pavements

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WOOD BLOCK PAVEMENTS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRED DWIGHT DANFORD

ENTITLED WOOD BLOCK PAVEMENTS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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INTRODUCTION.

The object of this thesis is to discuss fully the subject of Wood Block Pavements. A short description of the earlier forms and the development of this pavement to its present state, will be given. As European and American methods of construction differ slightly, they will be treated separately. A large part of the paper will be given to the comparison of this with other forms of pavement, and this will be made up largely of a compilation of the ideas of responsible engineers and others who have had experience with wood blocks. In conclusion will be given the specifications for wood block paving in a few cities which have used this form of pavement.

PROGRESS OF WOOD PAVING.

Russia is reported to have had wooden pavements several hundred years ago, but as no detailed record of them is obtainable, they could not have been used to any great extent.

The first wood pavements were laid in New York in 1835-36, and in London in 1839. These earliest forms, aside from the old corduroy roads, were round or hexagonal blocks placed directly upon the ground. The blocks were made of any available wood, were not treated, and were, on an average, about one third sap. They therefore rounded quickly on the edges, giving a very rough surface which hindered drainage and cleaning, thus making the pavement unsanitary and hastening its decay. Yet they were laid extensively in the middle west, and though neither durable or in any way satisfactory, were cheap and served their purpose in fast growing cities where finances would not warrant the laying of a more substantial pavement.

As an improvement over this first type, other forms of block were devised, many of which were patented. In the United States perhaps the most conspicuous of these was the "Nicholson", patented in 1848 and laid extensively in the ten years succeeding the civil war, to the great and lasting sorrow of all cities thus improved. Little or no care was taken with the selection of the timber used. Hard, soft, heart-wood, sap-wood, seasoned, and unseasoned woods were used indiscriminately. The blocks were sometimes dipped in hot coal tar or pitch, which served to cover up the defects and incidentally to seal up within them the moisture due to lack of seasoning, thus hastening dry or heart rot. The introduction of lath between the blocks served to make large joints. These admitted water under the pavement where it was absorbed, and the result was that the blocks swelled, causing the pavement to heave from its foundation. The use

of untreated plank on earth as a foundation was decidedly insufficient. That part of the pavement which was not heaved by the frost went down by the rotting of the planks.

Karri and Jarrah, very dense and hard Australian woods, have been laid extensively in England. In London these woods have shown a life of from fifteen to twenty years, but continued use has not entirely justified the hopes first entertained for them. Their structure is too dense to admit of impregnation with chemical antiseptics, without which they absorb water and swell. They are much more slippery than most native woods, and are not immune from decay, though because of certain antiseptic gum resins contained in them, they are less susceptible to rot than most native woods. In England, however, they are still used. Jarrah blocks were laid on Twentieth street, New York city, in 1895 but were removed in 1904. The cost of this pavement was about five dollars per yard, which would exclude it from extensive use in America even should it make a better pavement than our best creosoted native woods.

After the failure of untreated native woods, attention was turned to wood preservatives. The tendency has been to narrow down to the use of one material for the treatment of wood paving blocks, namely the dead oil of coal tar commonly called creosote. It is applied either pure or in mixture with resin, pitch or other insoluable materials.

Creosoted southern pine paving blocks are said to have been laid at Galveston, Texas, as early as 1873. This pavement, though laid directly on a subgrade of sand, gave good satisfaction for nearly thirty years, but was finally destroyed by the great flood of 1900. This good beginning was not followed up, and only within the last ten years has the matter received systematic attention in this country.

PAVEMENTS IN FRANCE AND ENGLAND.

The two most important cities of Europe in which wood block pavements are used extensively are Paris and London. In Paris the blocks are manufactured and laid by the city authorities, the various plants having a capacity of forty-seven thousand blocks or about one thousand yards per day. Two depths of block, six inch for soft and four inch for hard woods, are manufactured. There are nearly two million yards of this pavement in use in Paris.

The wood in most common use in Europe is Swedish deal, a rather soft, easily impregnated wood. About fifteen years ago, however, American red gum was introduced and used quite extensively in London. It is a better wood than Swedish deal but not so hard as Australian woods. It has little value for lumber so was thought to be a good substitute for deal. English engineers made the mistake of laying it untreated, and though it gave fairly good satisfaction, it began to decay after a time. This wood has now become valuable for furniture and is no longer used for paving.

The present methods of laying this pavement abroad differ only in particular features. In general they are as follows:- A foundation of concrete is laid upon the subsoil and brought to the form of the finished pavement. This foundation is a mixture of portland cement, sand, and crushed stone or coarse gravel in the following proportions: One part of cement, two to four parts of sand, and five to seven parts of crushed stone or gravel. A thin cushion coat, usually of sand or neat cement, is used between this foundation and the blocks. When sand is used the blocks are laid directly upon it and a roller is then run over the pavement until the surface is smooth. With a cement cushion coat a slow setting cement is required. It is brought to the form of the surface by means of a template, and the blocks are set in this bed of mortar. When a few courses have been put down they are brought to an even surface by ramming.

The joint fillers are of different materials, but sand is perhaps the most commonly used. It serves the purpose very well as it will work into the joints under traffic. Other materials used are tar, asphalt, and cement.

A rigid specification is usually placed upon the blocks. No variation greater than one sixteenth of an inch in length or breadth, and no measurable variation in depth is allowed. The blocks are also required to be kept carefully protected from sun and weather after treatment until they are laid. This prevents deterioration from checking.

Joints of different width have been tried with varying degrees of success, but the most common practice now seems to be to lay the blocks close together. Mr. Frank Latham, Borough Engineer and Surveyor, in 1902 says: "Close jointing is to be commended in all description of road pavements. Wide joints have been adopted to a great extent but the system is dying out. Such pavements after a time become quite uncomfortable to ride over, owing to the jointing material wearing down below the surface of the pavement. This is also hard on the blocks, and leaves greater facilities for absorption, causing a greater amount of expansion and the material to become saturated to a large degree with unsanitary matter."

The traffic on the principal streets of both Paris and London is enormous. On the Rue de Rivoli, Paris, there are over sixty-five thousand teams a day, or three thousand four hundred per yard width of street. There are over sixty-six thousand teams per day on the Avenue de la Opera, or two thousand per yard width of street. On Fifth avenue there are over eight thousand four hundred teams and on Madison avenue seven thousand per day. Under this traffic native woods wear on an average one centimeter, or four tenths of an inch per year, and are allowed to wear until four of the original six inches are worn away. This gives, under the heaviest traffic in the world, with inferior woods, a life

of ten years. Horses are not allowed to have calks on their shoes. This makes the wear less and also indicates that the pavements are not slippery. This average wear is exactly the same as is noted for granite in the same city.

In the report of the Parish of St. Mary Abbots, Kensington England, 1900, the surveyor said: "Kensington High street was paved with dipped blocks in 1891. These have lasted for eight years. Wood creosoted under pressure has lasted on other roads for twelve years. Under traffic of forty thousand teams per day the life of wood pavements on Strand street, London, is given in official reports as seven years. Very few granite pavements would be in good condition at the end of that time."

WOOD PAVEMENTS IN THE UNITED STATES.

It is only within the last ten or fifteen years that wood block paving has received systematic attention in the United States. Before that time improper methods of construction had placed the pavement in disfavor.

One drawback in the use of wood for paving has been the lack of knowledge of the wood itself. For example, sapwood has always been thought to be both weaker and more subject to decay than heartwood. It is strictly excluded from most wood paving specifications, all-heart blocks being demanded. The inclusion of sapwood undoubtedly caused the untreated blocks of former years to wear unevenly and to decay quickly. Recent tests show that under equal conditions of moisture content, the sapwood of many species is as strong as the heartwood. It is usually less strong because the wood is rarely used under conditions where the moisture content of the sapwood is as low as that of the heartwood. Creosote treatment, with proper previous seasoning, reduces the moisture content of each to an approximately even minimum, and the heavy charge of oil now customary in American paving block treatment, prevents subsequent absorption of moisture beyond a small per cent. After five years there is no measurable wear on either the heart or sap portions of untreated Norway pine blocks laid in the city of Minneapolis.

The wood which has stood out as a leader for paving use is long leaf Georgia pine. It is a very hard and dense wood of even quality, and has given better satisfaction than most of the other species tried. This timber has been used extensively in construction work, and the supply has rapidly diminished until it was found a few years ago that the increasing price and decreasing quality of Georgia pine would not warrant its use for paving purposes. It therefore seemed evident that the manufacturers must find a substitute for long leaf yellow pine. The United States government has also taken a lively interest in

this question, and through their suggestions as well as through those from other sources, it was concluded that one of the gum woods extensively used in the south and known as black gum, possessed all the requirements for a successful paving material. This wood, on account of its tendency to warp, has been used very little for other purposes. It resembles the Australian hard woods that were formerly used abroad for paving, but while very tough in grain, it is not as hard as these woods and not as proof against decay. It was felt, however, that, properly treated, it would make a block equal or superior to long leaf yellow pine, and actual tests in service indicate this to be the case. Blocks of this character were laid on Hudson street New York, between the tracks of the Metropolitan street railway company, extending from Dowdick to Waite streets. After about one year of service, they are in fully as good condition as the pine blocks adjoining them. This wood possesses a great advantage of being of uniform texture throughout and does not have any great difference in durability between heart and sapwood.

This experiment shows that black gum is a very good substitute for Georgia pine. Tamarack, Douglas fir, western larch, white birch, Norway pine, and hemlock are all used to a considerable extent. In the north Douglas fir and tamarack seem to be in special favor.

Treatment.

Wood has an exceedingly complex physical structure. Almost the entire substance is of organic nature and can not be produced artificially. It is composed of a series of closed cells arranged as in honeycomb, but instead of being approximately the same size, their sizes and shapes vary greatly, sometimes in the same piece.

There are in all woods, besides the vertical columns of cells, horizontal rows occuring at short intervals between the vertical columns and closely

filled in them. These horizontal rows are narrow vertical plates, varying from a few thousandths of an inch to an inch or more in height, arranged radially in the trunk of the tree. The vertical cells are closed but the horizontal ones are not, and it is in the latter that the preservative is forced.

A word should be said concerning the decay of timber before taking up the treatment. The decay of plant body is purely an organic process, due to the activities of low forms of plant life, called bacteria and fungi. These are among the simplest forms of life, often consisting of a single cell, microscopic in size. They feed upon the cell walls of the wood structure but in addition to food they must have heat, air, and moisture for their growth. Ordinary climates furnish sufficient heat so it is only by depriving the animal life of food, moisture or air that decay can be prevented.

The best method of doing this is by injecting poisonous substances into the cellular openings of the wood. Of the many antiseptics which have been proposed, only two are in common use in the United States. They are zinc chloride and creosote oil. As the former is soluble it is not suitable for use in paving blocks and will not be discussed.

Creosote oil is not a modern invention. In a patent dated 1838, Mr. John Bethel mentioned under the term "Creosoting", eighteen different substances, and among these, a mixture consisting of coal tar thinned with one to one and a half times its quantity of dead oil distilled from coal tar. This is claimed to be the origin of the so called creosoting process. From that day to this there has been a steady increase in the use of treated material, consequently continued improvements in the methods of creosoting.

Mr. Carl Crawford, in a paper before the Association of Wood Preservers, January 1907, shows how marked these improvements have been. He states that: "The last few years have witnessed a great activity in wood preservation

throughout the entire country, and this activity has manifested itself along the following lines: First, the increase in number and capacity of treating plants. Second, the improvement in existing methods, and the introduction of new methods, and the development of new methods destined to meet American requirements. Third, the promotion of more careful and detailed study of the technology of American woods, and an investigation of the constituents and properties of the preservatives in general use".

Bulletin Number 14, United States Department of Agriculture, expresses the conditions to which the ideal preservative should conform.

"1. It must be poisonous to bacteria and other destructive agents.

"2. It must be capable of easy injection, and when once in the wood, must remain there.

"3. It must penetrate all the cells of a piece of timber.

"4. It must be clean."

The above investigations exclude from the list of preservatives those which employ salts soluble in water, and fix one's attention on the Creosoting method, which is without doubt the most useful and best method yet suggested. The dead oil is antiseptic and insoluble. It fills the wood cells excluding moisture and preventing attacks from elements of decay.

The dead oil of coal tar, or creosote oil, is a product of the distillation of coal tar. Distillates of coal tar arrange themselves into three groups: Naphtha - those lighter than water; dead oil or creosote - those heavier than water; and pitch. The first group is very volatile at ordinary temperatures so is not a suitable preservative. The third group finds its greatest use at present in the manufacture of roofing paper, the construction of the so called tarred gravel roofs, and as a filler for pavements. The second group includes all the essentials necessary for the preservation of timber. This group con-

be further divided into substances, either acids or bases.

The question of the quality of the creosote oil for various kinds of work is a very important one. The conditions under which the different grades of timber are to be used have a very important bearing on the quality of oil as the quantity of oil to be injected.

Ordinary creosote oil is not entirely waterproof, but it has been found by experiment that it may be made so by adding resin to it. When this mixture is used in treatment, we have what is known as the creo-resinate process. Plain creosote softens the fibre of the wood to a certain extent, but resin has been found to work against this softening quality of the oil, and in addition to waterproofing the blocks it hardens them and leaves them firmer in texture than the natural, well seasoned wood.

A few years ago the problem of treating blocks with creo-resinate mixture was complicated by the advance in price of resin from one dollar forty cents to four dollars seventy cents per barrel. The increase in price naturally suggested the use of another material, or a reduction in the amount used. Great difficulty has been found in obtaining any material which will take the place of resin for waterproofing and hardening the blocks. A thorough investigation of the subject led to the conclusion that by improving the quality of the oil, the resin content could be reduced. Creosote oil is generally tested for its specific gravity and its volatilizing points. By increasing the specific gravity and greatly reducing the amounts that evaporate at given temperatures, a far heavier and more permanent oil is secured, and with the use of such an oil the amount of resin may safely be cut in half. These conclusions are the results of long and continued experimentation, both as to the possibility of securing thorough treatment with oils of this character, and as to the waterproof qualities of the resulting product. It has also been found that blocks thus treated

with oils containing only twenty to twenty-five per cent of resin are more waterproof than blocks treated with lighter oils containing fifty per cent of resin.

Thus it is seen that although the field is still open for the development of an ideal preservative, a very good one has all ready been obtained, and the success of the later pavements has shown the possibilities of wood block paving.

The Republic Chemical and Creosoting Co. of Indianapolis, Indiana, by a series of experiments has obtained a creosote oil they call 'kreodone', which has met with very good success. The oil seems to be a permanent preservative, and it also materially increases the toughness of the wood. This latter quality is clearly shown in the treatment of long leaf yellow pine blocks. This timber in its natural state has a resistance to crushing of about eight thousand five hundred pounds per square inch. Treated with kreodone the resistance was about eleven thousand pounds per square inch. In tests on this oil recently conducted by the city of Indianapolis, it was found to be non-soluble and non-volatile. The chemist who conducted the tests reported that the blocks treated with this oil were tested for variations in area of exposed surface and variation in weight after drying for twenty-four hours at two hundred degrees Fahrenheit, and immersing in water for the same length of time and at the same temperature. The blocks showed no variation in area of exposed surface after this test and one block showed no gain in weight after immersion. The others showed a gain of seven tenths of one per cent in weight.

Foundation and laying.

For the most satisfactory service, wood block pavement requires a concrete foundation. This is usually made from five to six inches thick, although in some lightly traveled streets it is made four inches, and on some heavily

traveled streets it is made seven inches. As a cushion for the blocks either portland cement mortar or sand is used. The former is not considered superior by most engineers. The bearing is permanent, and if carefully surfaced, the blocks can be made as even as desired. If the grout is mixed slightly damp and the blocks laid in it immediately, it provides as good a compensation for minor inequalities in the height of the blocks as sand. Some use the cement grout in surfaces and allowed to set, after which a thin coat of tar is applied and the blocks imbedded in it. Sand makes a satisfactory cushion on light grades where the foundation is solid. It is sometimes preferred on the ground of greater elasticity and power of accommodation, and it has the merit of being cheaper than cement. But on grades, sand is not so good. If water gets under the blocks it is likely to carry the sand to the foot of the slope and thus seriously derange the pavement. On bridges if there is much crown to the roadway, the vibration of the structure is likely to shift the sand from the center toward the gutter. For bridges, however, the usual practice is to lay the blocks directly upon planking.

The blocks should be strictly inspected, especially as to the imperfections of sawing, as to knot holes, decay, defective corners or edges, as to squareness of the angles, and as to thoroughness of impregnation. Voids due to any of these imperfections often can not be properly filled by the joint filler, and are very detrimental to the pavement.

Sapwood is entirely excluded by most good paving specifications. Under existing market conditions, however, it is quite impossible to obtain strictly all heartwood. The true long leaf pine has usually so narrow a sapwood that it may be rejected without damage to the life of the pavement. But commercial long leaf pine is also seldom free from an admixture of loblolly pine. This is a sort of second growth which has come on very rapidly and is nearly

all sapwood. A better specification than that excluding sapwood, would be one excluding fast grown timber, since it is the porous wood resulting from fast growth rather than the presence of sapwood, which unfits timber for pavement use.

The angle at which the courses are laid is a matter of some importance. The most natural angle is that of ninty degrees to the curb. Probably the greater part of the wood pavements in the United States has been so laid. But this angle permits the calks of the horses shoes to strike in a direct line with the joints, and subjects the pavement to a wear and tear which may be largely avoided by laying the courses at an oblique angle. With the courses laid at such an angle, the thrust of the pavement in case of expansion will impinge in both directions upon the curb, and the transverse expansion joint may be entirely dispensed with.

The oblique angle which most naturally suggests itself is forty-five degrees, and a large amount of pavement has been laid that way. Theory has, however, developed an objection to this angle. Transverse expansion in wood takes place in two directions, tangentially to the rings of growth, and radially to them. Of these expansions the tangential is the greater. The common method of sawing blocks from a log is such that a majority of the blocks have their long axes in a plane tangential to the annual rings, or at least nearer that plane than the radial one. Therefore the force due to tangential expansion will be exerted chiefly in the direction of the courses of the blocks, and the lesser radial force will be exerted at right angles to that direction. The angle of forty-five degrees does not compensate the different expansions in the wood, and so poorly conducted pavements following straight courses have been developed.

The angle between forty-five and ninety degrees has therefore been bisected by some engineers, making the angle with the curb sixty-seven and one

half degrees. This solution was an entirely proper one, but it would [illegible] avoid the difficulties experienced at the previous case.

The question of proper joints to be used in wood block pavements has received a great deal of attention. Like most questions of a similar nature, it is impossible to generalize and say that one form of joint is the best for all conditions. On streets where the traffic is heavy, the blocks are laid close together and the action of traffic tends to expand the heads of the blocks slightly, resulting in the closing of the joints so that the surface of the street is almost as homogeneous as the surface of an asphalt street, and no crevices for the entrance of water exist. No wood block pavement will be affected by the water which runs over it, but water can run under the blocks through the joints, and remain there for days in the process of being soaked up, expansion occurring where it takes place, even in the most thoroughly treated blocks. The expansion usually arises from the character of the wood block rather than from the character of the treatment. It has, therefore, been found that on streets where the travel is not sufficiently heavy to cause the obliteration of the surface, [illegible] waterproof or expansion joints should be provided. In the Borough of Queens in 1907 some fifty thousand square yards were laid on streets of moderate travel in the following way:- Half inch expansion joints were left along the curb and along the rail on streets with car tracks. These joints were filled with paving pitch. Similar joints were placed across the street at intervals of one hundred feet. It is interesting to note that not only have there been no evidences of any swelling on these streets, but it does not appear that the expansion joints have been brought into use. This would indicate that in this instance the expansion joints were unnecessary. Nevertheless other experiences have shown that it is a wise precaution on all streets paved with wood.

In some cities expansion of pavements is provided for by leaving one

[illegible] surface with a [illegible] end of paving [illegible]. This [illegible] [illegible] [illegible] the pavement [illegible] [illegible] [illegible]. In spreading the hot pitch over the surface and [illegible] [illegible] the joints, a [illegible] amount is left on the surface, and under the action of the sun it becomes very sticky and disagreeable. When the pitch gets in this shape it is tracked into the automobiles and into the buildings, so it is unsatisfactory to the property owner. Some effort is made to pour the joints with the pitch, but so far as any workman can accurately pour joints of this character without getting some pitch on the surface when they do the joint.

In pitching the joints care should be taken not only to get as little on the surface as possible when pouring it, but also to spread and even the surface where the pitch is not, for when the surface has all been ground off in a reasonably short time.

A cement grout is very quickly applied, and the surface of the street may be swept clean of this top dressing within a short time. In fact, under these circumstances there seems to be little [illegible] for any necessity of using the sand top dressing at all. The cement joint gives no room for expansion, but this difficulty may be overcome by making [illegible] joints.

COMPARISON WITH OTHER PAVEMENTS.

Recent inquiries among drivers of various kinds of vehicles, as to their opinions as to the desirability of different kinds of pavement, were made by the City of Indianapolis. Of [illegible] answers received, fifty-one favored asphalt, one hundred nine favored granite, one hundred sixteen macadam, and seventy-seven fifty or more, were favorable to wood blocks. Although this can not be taken as conclusive proof of the superiority of this kind of pavement, it does show that in the minds of many intelligent men. The experience with wood block pavements in this country has been exceedingly unfortunate, due partly to the fact that inferior material was often selected and bad methods used in laying. The recent introduction of better material and correct methods, gives good grounds for changing this bad opinion of wood, so that it is likely to become one of the most popular pavements where traffic is heavy.

The best quality of granite is generally considered to be the most durable pavement that can be laid. For this reason it is universally used on the heavily traveled streets of most large cities. It cost more, but is considered more economical to use because of the longer life and the ease with which it can be repaired. It lasts from ten to thirty years according to the traffic. It may seem absurd to some, to claim an equal or greater life for wood pavements, but that is what the makers of this latter pavement are doing, and and the results from recent tests seem to show that such will be the case.

To test the quality of durability, the chief engineer of the Metropolitan Traction company, New York, has had a strip of wood laid between two car tracks on Hudson street, where the traffic is exceedingly heavy. In this particular spot the best granite never lasted more than two and a half years, usually less than this. Along each of the wood on a parallel track he

laid an equal amount of granite. At the end of taking the report the test had been down six months, and the wood seemed to be standing the wear better than the granite. The chief fault of granite is that it chips off around the edges of the block, thus causing the surface to become similar to that of a cobble stone pavement. In the wood this fault does not appear. After two years' wear, blocks were taken from the center of Tremont street, Boston, and were found to have decreased uniformly in thickness about one eighth of an inch, or an average of one sixteenth of an inch per year. This was not due alone to wear, but partly to the compacting of the upper fibres of the wood.

Rush street bridge over the Chicago river carries without doubt the heaviest bridge traffic in the United States. By actual count in 1900, it was found that there were on the average about eleven thousand vehicles, mostly heavy trucks and drays, passing daily. Prior to 1899 this bridge had been paved time after time with untreated wood. The condition of pavement was brought to the attention of the city engineer, and an investigating committee was appointed to look into the matter. The committee reported favorably, so it was decided to lay the creosoted wood on one half the bridge and on the other half with the usual untreated wood. This was done, the creosoted wood being in the form of three strips laid edge up and grouted. This part was left under a ten year guarantee.

At the end of four years the treated strips showed a very even wear of only one eighth of an inch, while the untreated wood was very uneven, from one to two inches. This latter left the surface in a shocking state.

Major Hirsteen, in his annual message to the city council on April, 1900, after referring to the experimental showing of the pavement, said: "The traffic on this bridge is of the heaviest character, the bridge being traversed from end to end with all the heavy traffic of a large city, and carrying all the traffic of a large part of

[illegible] section to the heavy traffic of the [illegible] district, from the docks and from the railroad freight houses, the paving is judged to be, in all probability, as severe as existing at any single place of paving in Chicago."

This pavement was constructed by [illegible] in 1903, and found to be in good condition. Although in service some years, the surface was not at all rough.

A short section of the pavement was laid in Russell Square, in South Park commissioners' Lake experimentally, a small section of creosoted wood block pavement on Michigan Avenue in front of the Auditorium hotel. This section was especially well put in, being five inches laid on from seven to eight inches of concrete. In August, 1902, Mr. J. F. Foster, general superintendent and engineer of the South Park board of commissioners, said: "The pavement is a most excellent specimen of creosoted block pavement. It is in practically as good condition now as when laid, although the traffic on it is very heavy. No repairs have been made on it and nearly every one who [illegible] I have taken considerable interest in it is greatly surprised to learn that it is in such excellent condition."

Although now in its ninth year of service, this pavement is in almost perfect condition, in fact in the every appearance of a new pavement. Critics have pronounced it the most perfect piece of pavement ever laid, and a mile of first-class [illegible] for many years has been practically [illegible].

The [illegible] of New York City in laying its [illegible] wood blocks, ranks as a great [illegible] for the manufacture of this pavement. New York has been for years confronted with the fact that it must have heavy trucking to be done in its office building district. The position of the city - [illegible] at the lower end of the island, with the water front [illegible] on the

stone without railway connection, makes it necessary for all or practically [illegible] work of the sort to traverse the business district on the way to the freight and [illegible] depots. It is impossible to restrict the traffic to any special route, as all the main ways are more or less equally congested.

In a few cases asphalt has been laid on streets that are [illegible] necessary for the trucks. With these exceptions, all streets were paved with granite or stone, and the noise was almost unbearable. Offices on lower floors of skyscrapers could not [illegible], because the noise of the traffic made it impossible for business men in the offices to converse without keeping the windows closely closed.

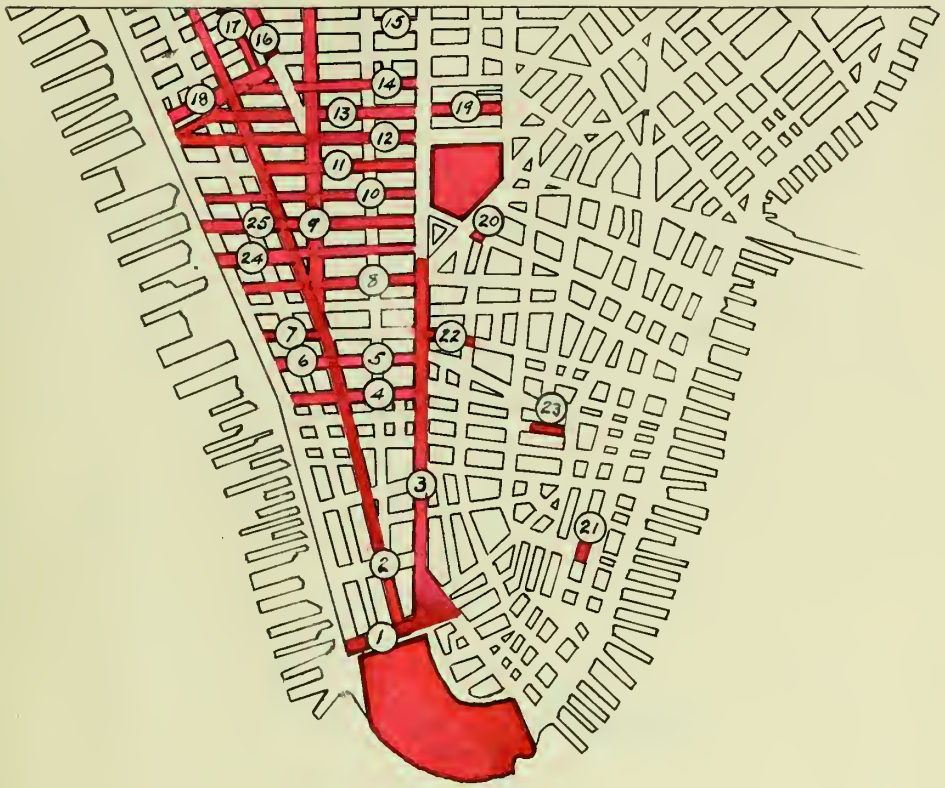
The first hint of relief from this [illegible] noise came with the laying of the wood block pavement on West Broadway. This was adopted [illegible] as a test of its ability to endure the enormous traffic. The result [illegible] it was found that traffic had no more effect on this street than on country roads. Almost immediately, petitions were sent [illegible] asking for the extension of this pavement to every [illegible] street. These petitions were signed not only by the owners of the offices, but also by the largest trucking concerns of the city. The latter [illegible] the significance of the fact that this form of pavement is more desirable for horses and trucks than the granite or stone.

The continual [illegible] of the Bureau of Highways, [illegible] pave [illegible] the financial district, met with universal approbation. Many of the streets are already paved with noiseless pavement, [illegible]. Broadway, from the Battery to the City Hall Park, is being covered with wood blocks this spring. (20)

The following is an extract from the New York Globe, [illegible] shortly after the laying of West Broadway. "Public [illegible] pavement [illegible]

GREATER NEW YORK.

Showing Streets Paved with Wood Blocks.



1. Battery Place
2. Greenwich St.
3. Broadway
4. Liberty Street
5. Cortland Street
6. Cortland Street
7. Day Street
8. Vesey Street
9. West Broadway
10. Murray Street
11. Warren Street
12. Chambers Street
13. Reade Street
14. Duane Street
15. Worth Street
16. Hudson Street
17. Staple Street
18. Duane Street
19. Reade Street
20. Beekman Street
21. Old Slip
22. John Street
23. Cedar Street
24. Barclay Street
25. Park Place

has just been laid on Broadway from the Battery to Vesey street over the [illegible] route. The possibility of a pavement of wooden blocks enduring under the traffic [illegible] will face on Broadway, excites considerable skepticism. It seems hardly possible, but it is a fact that these blocks laid on a concrete foundation, such as was prepared for them on Broadway, will outwear the stones which they replace. The granite blocks pulverize and polish under traffic, becoming round and rough like cobble stones. The result is that heavy traffic creates an unbearable [illegible] so that even office workers along the streets could not [illegible] keep windows [illegible] open. In the past it was impossible to do this because the roar of the streets made conversation and the transaction of business almost impossible. The wood block pavement, however, overcomes this objection very successfully.

"As the blocks are [illegible], it is impossible for them to splinter. The fact that they are pressed tightly together, practically without joints, prevents their splitting or becoming [illegible] for wear. Traffic only makes the pavement harder, crushing down the fibres in a tough [illegible] mass, upon which the blows of the horses hoofs and the weight of vehicles have no effect.

"A duplicate of this pavement laid on one of the heaviest traveled streets of Boston five years ago, [illegible] year after the third year, and it is not likely to need repairs [illegible]. In support of their claims, the manufacturers cite a similar pavement in Galveston, Texas, where creosoted blocks, laid on Market street with no other foundation than sand, were in good condition after eighteen years of use."

For general work in Greater New York, wherever the pavement has been laid, the blocks are four by four by eight inches, all heart, long leaf pine, creosoted. Specifications require [illegible]

being entirely free from the noise and jar of the granite block. The best of the brick laid on the bridge showed an absorption of only one-eighth ounce of water per cubic foot. The foundations are flat and a half inch of concrete and a one half inch cushion of sand separate the concrete and brick. The joints are filled and kept filled with cement.

An extract from the report of the Market Street Merchants' Protective Association of Philadelphia, which inspected some of the streets in New York laid with grouted brick, was published in the May, 1905, number of Municipal Engineering. The extract says: "After going over the territory, more than one-half the total number of miles in the district of your commission of any kind of brick paving was being used by some of the large cities in the world, for the purpose of paving the streets. The brick used in New York was many times better than the best grade in Philadelphia paved with the most approved Belgian brick. In fact, the difference was so apparent that your commissioners found that the Philadelphians had been mapping again, and more about five years behind the times.

"To assure ourselves that this impression was correct, your commissioners called on a number of merchants whose places of business front on streets paved with brick, and did not find one dissenting voice. On the contrary, many of those merchants were enthusiastic in the subject, and some one of them said he would do if the many advantages of this kind of paving.

"The points were called to our attention by owners over, who we interviewed. Our attention in every case was called to the acoustic properties of wood block paving, and in many cases the merchants absolutely claimed that they could trace a direct increase in business since a street had been repaved, and a decided advantage in the conduct of their business, as they no longer had the added care of trouble in hearing telephones, nor did they experi-

since my interview which is commencing [illegible] Cincinnati, never been called to this extent. In reference to this question, we beg further to state that your communication was received in the midst of heavy drays passing to and fro, for a period of at least fifteen minutes, and during that time did not experience the least difficulty in hearing the above words in speaking in an ordinary conversational tone. Another point called to our attention was the almost absolute lack of dust and dirt, and which recommends it for [illegible] can safely say that the wood block pavement in use in New York [illegible] beyond doubt the cleanest streets we have ever seen anywhere. This condition is largely due to the ease with which this pavement is cleaned, either by flushing or a heavy rainfall.

"Together with a number of other questions, we have put a point to each every merchant: 'If your street were to be repaved, would you favor wood paving?' In every instance the answer was a decided yes."

A somewhat different method of laying was adopted in Brooklyn recently in the case of two bridges paved, the Washington Avenue bridge over the Wallabout Canal, and the Metropolitan Avenue bridge over Newtown Creek. In both cases the blocks were laid directly on the yellow pine flooring planks on the intervening channels. As the top of the truck rail was only three inches above the floor, three inch blocks had to be used. On the latter bridge, the flooring was even and no bad results were noticed, but on the former, the flooring was badly warped, and the uneven bearing caused many of the blocks to split under heavy traffic. This splitting has, however, done no apparent damage to the pavement. It is guaranteed for five years although the planking previously used has to be renewed every year at a cost of about one dollar twenty cents per square yard. For five years this would amount to about six dollars, and the wood blocks cost, including the guarantee, for about ten dollars per square yard.

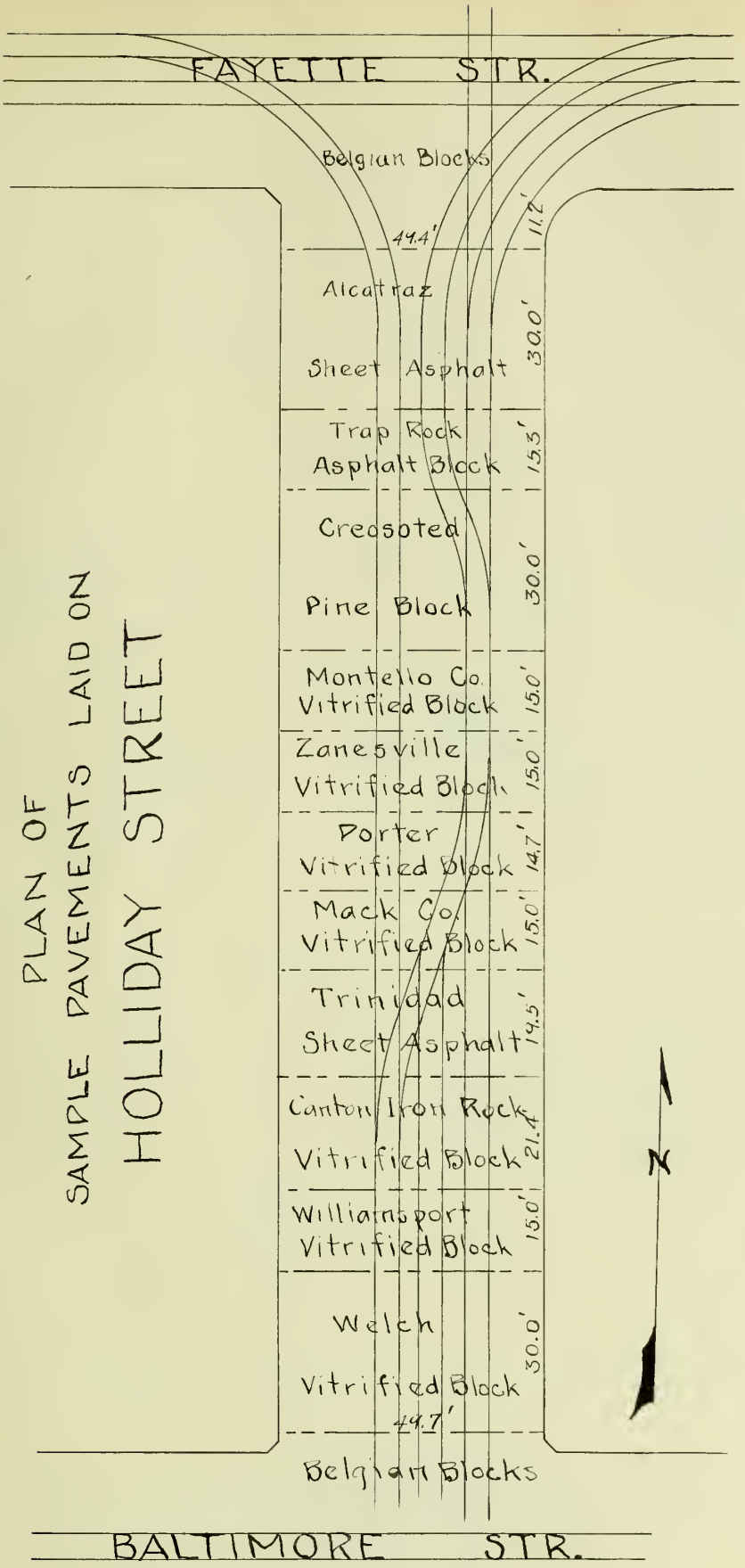
Another form of construction is found on the Williamsburg to East River bridge. Here the blocks are laid directly on a surface formed by laying steel channels lengthwise of the bridge. This surface is covered with asphaltic cement, and the blocks laid therein. This construction is of recent date, and is not fully proved.

In 1900 the authorities of Baltimore, Maryland, determined to make a comparative test of a number of selected pavements. Accordingly, Holliday street, between Fayette and Baltimore streets, was chosen, and the city engineer invited the various street paving contractors to put down a sample of their pavements as test specimens. The street lays north and south, and the block measured one hundred fifty feet long and forty-nine and one half feet wide. This street was selected by the city engineer for these tests because of the large amount of travel, the street car cross-overs, and the clear space of eighteen feet between the west rail and the west curb, thus giving the worst and best conditions on the same street.

The accompanying diagram shows the division of the street into eleven strips or test sections, varying from fifteen to thirty feet in length. There were several makes of vitrified brick, two sections of sheet asphalt, one of asphalt block, and one of creo-resinate wood blocks.

During the first year it was evident that some of the sections were going to show comparatively unsatisfactory results. At the end of four years the superiority of the wood blocks was clearly evident, and in 1907, after seven years, the test was finally concluded, as all of the paving with the exception of the wood block, was in decidedly poor condition.

The results of these tests were so much in favor of the wood blocks that this pavement has extended over the whole street. By special permission from the city, practically all the old wood blocks taken out of the thirty foot



PLAN OF
SAMPLE PAVEMENTS LAID ON
HOLLIDAY STREET

section was laid again in the new work. During their seven years of use they had not worn enough to interfere with their use with the new blocks, and were practically as good as when originally laid. Even the great Baltimore fire which raged all over this neighborhood, had done no damage worth noticing, although some of the blocks were slightly charred by red hot embers which had dropped upon them.

One of the severest tests this pavement has ever been subjected to in America, was at the foot of Market Street in San Francisco, where all the Southern Pacific freight trains emptied their immense cargoes of heavy freight. Market Street at this point took the entire traffic, and the paving has long been the source of much trouble. In 1892 a pavement of granite blocks was entirely destroyed by traffic, and in 1893 two asphalt pavements were completely worn out. In 1894 a pavement of wood blocks on six inches of concrete was laid, and when reported in 1898, after four years, it showed little wear and no break in the surface.

Another extraordinary showing of wood block pavement has been made on California street, San Francisco, in front of the palatial homes of the multi-millionaires of that city. This pavement was put down in 1877, and when inspected in 1898 by Mr. H. L. Collier, commissioner of Public Works of New York, was in excellent condition. Not the slightest irregularity was perceptible on its surface. There was no sign of wear or decay, and the unified surface gave it the appearance of the best sheet asphalt. Some of the blocks were cut out and, although they had been down for twenty-one years, were found to be perfectly sound.

These few examples can not, of course, be regarded as final. There have been instances in which creosoted blocks have given poor results. But it should not be forgotten that poor preservative treatment of the wood, or faulty

construction of the pavement may cause the best wood to fail. The cited instances of successful pavement indicate that such errors are responsible for the failures which have occurred, and that wood block pavement, properly prepared and laid, should be credited with a durability greater than as usually given it.

The United States Forest Service, in investigating wood block paving in the United States, sought opinions from the engineers of a number of American cities who have had experience with modern creosoted block pavements, as to the comparative qualities of different kinds of pavements. The results of the inquiry are given in the following table. Under the per centage column the various qualities desired in a pavement are assigned proportionate values, the total being one hundred points. The pavement ranking first under any given quality is given the full quality per centage, the rest grading down from this value in proper proportion. The figures given are the averages of ten replies to the inquiry.

COMPARATIVE VALUE OF DIFFERENT PAVEMENTS.

Pavement qualities.	Percentage.	Granite.	Sandstone.	Asphalt (sheet)	Asphalt (block)	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost)	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	17.5	6.0	14.0
Ease of maintenance	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low traction resistance	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Freedom from slipperiness (average conditions)	7	5.5	7.0	3.5	4.5	5.5	1.5	4.0
Favorableness to travel	4	3.5	3.5	4.0	3.5	3.0	3.0	3.5
Acceptability	4	2.0	2.5	2.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
Total number of points	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0
Average cost per square yard late, 1905		$3.26	$3.30	$2.30	$2.29	$2.06	$0.99	$3.10

TEST OF PAVING BLOCKS.

The writer obtained from the Kettle River Quarries Co., Minneapolis, eight sample blocks for testing. The blocks were of Tamarack, four by four by eight inches, and were treated with sixteen pounds of creosote oil per cubic foot of wood. They were tested for absorption, and expansion of exposed area, after drying for forty-eight hours in air at seventy degrees Centigrade, and then immersing for forty-eight hours in water at twenty degrees Centigrade.

The following table shows the results obtained:-

Specimen number	Weight in air after drying grams	Weight in air after soaking grams	Weight in water after drying grams	Weight in water after soaking grams	Absorption per cent	Expansion per cent
1	1400.3	1[illegible]	-2[illegible].1	-3[illegible]	1.3	2.3
2	1[illegible]	1[illegible]	-2[illegible]	-2[illegible]	[illegible].2	2.3
3	1347.4	1420.7	-3[illegible]	-332.3	2.3	2.1
4	1308.9	1443.2	-301.3	-323.8	2.7	2.1
5	1307.3	1[illegible]	-3[illegible]	-321.4	2.8	1.9
6	1478.1	1540.0	-226.6	-193.3	2.3	1.9
7	905.5	975.0	-324.3	-30[illegible].1	[illegible].5	1.4
8	1[illegible].2	1[illegible].4	-20[illegible].0	-1[illegible].0	3.2	3.0
average					2.4	2.3

SPECIFICATIONS FOR PAVING BLOCKS. MINNEAPOLIS.

The wearing surface shall be composed of creosoted Norway pine, tamarack, or fir. No second growth lumber will be accepted. Bidders shall submit separate bids on the following:-

A. A block 4" in depth, 4" in width, and 4" to 10" in length, treated with 12# of creosote oil to the cu. ft.

B. A block 4" in depth, 4" in width, and 4" to 10" in length, treated with 10# of creosote oil to the cu. ft.

C. A block 3 1/2" in depth, 4" in width, and 4" to 10" in length, treated with 12# of creosote oil to the cu. ft.

D. A block 3 1/2" in depth, 4" in width, and 4" to 10" in length, treated with 10# of creosote oil to the cu. ft.

E. A block 3" in depth, 4" in width, and 4" to 10" in length, treated with 12# of creosote oil to the cu. ft.

F. A block 3" in depth, 4" in width, and 4" to 10" in length, treated with 10# of creosote oil to the cu. ft.

All blocks shall be rectangular, of a uniform depth and thickness, free from sapwood, cracks, checks, worm or knot holes, or other injurious defects affecting the life of the block or the laying of the same, and shall be made of sufficiently dry and well seasoned material to admit of proper treatment as hereinafter specified.

SPECIFICATIONS FOR TREATING PAVING BLOCKS. MINNEAPOLIS.

After the blocks shall have been made of the specified kind of material, and all the defective blocks have been removed, they shall be placed in an air tight chamber, when, by the use of heat and vacuum, all the sap and moisture shall be removed.

The vacuum shall be from 20 to 28 inches and the heat shall not be carried to such an extent as to injure in any manner, the fibre of the blocks.

While the chamber is under vacuum, the creosoting mixture, of the quality as before specified, and heated to a proper temperature, shall be admitted and pressure added and retained and the blocks have absorbed the required amount of the mixture for each cubic foot of timber, it shall the creosoting mixture shall have entirely impregnated and thoroughly filled the timber.

CREOSOTE OIL FOR PAVING BLOCKS.

The oil to be used in the treatment of the blocks shall be a pure heavy, creosote oil, obtained from coal tar only, and of the following quality:-

A. The specific gravity of the oil shall be at least 1.05 at a temperature of 20° C.

B. It shall be completely liquid at 38° C., and must not deposit on cooling to 22° C.

C. It shall be subjected to a distillation test, as specified below, and shall conform to the following requirements:-

100 grams of the shall be placed in a 8 ounce flask, fitted with a thermometer, the bulb of which shall be placed 1/2" above the oil, and not moved during the test. The distilling flask of the oil shall be from 20" to 24" from the bulb of the thermometer, and the neck shall be covered so as to prevent too rapid radiation. The per centages are by dry oil and 0, Hough.

Up to 150° C. [illegible]

" " 170° " [illegible] 0% to 2%

" " 190° " " 5% " 15%

" " 210° " " 10% " 30%

The distillation should be gradual and up to 315° C. should be completed in 30 minutes.

The specific gravity [illegible] at 31.5° C. should be [illegible] 1.11.

D. In the process of [illegible] in the CaCl, not more than 5% of [illegible] should be [illegible]. It must, accordingly [illegible] for the same.

SPECIFICATIONS FOR WOOD BLOCK PAVEMENTS. BOSTON.

Creosoted Wood Paving Block.

(1) All timber to be of the species of Georgia or Florida yellow pine, free from sap, free of all unsound or loose knots which would be detrimental to the life of the wood. No second growth timber will be used.

(2) Blocks, except as otherwise noted, to be 6" deep, 3" wide, and 9" long, uniform in depth, width, and length, and sawed true and square.

(3) Blocks are to be treated as follows:-

The blocks are to be placed in an air tight cylinder, and from the ends air until the dry heat is raised to 220° F. The air pressure, for the first hour, is to be maintained at 25# per square inch. The heat is then increased, the pressure applied, and both are held steady for one hour. The heat is then shut off and the tank is allowed to cool for one hour. At the end of this time the heat is to be increased to 220° F. and the pressure to 40#. The pressure is then blown off and the air pressure reduced. Vacuum is then applied until about 25 inches is reached, and while under vacuum the creosote oil is run into the cylinder at 175° to 200° F. and hydraulic pressure is applied, reaching 200# pounds per square inch, and kept at this point until 21 or 24# of oil have been absorbed. The amount of oil to be used is to be such a quantity as will fill the cylinder, plus about 10% of room at about 100° F. to run, and hydraulic pressure of about 200# applied for one half to one hour.

(4) The blocks are to be laid close, on a cement concrete foundation six inches deep as hereinafter provided, and at such an angle to the curb as directed by the superintendent, on a one inch cushion of clean screened sand,

and are to be driven at highly regularly as possible at every stroke rate.

(b) The joints between the fillers, between the end and the pavement and between other fillers should be filled flush with the pavement surface. The joints are then to be filled with paving joint, conforming to Specification No. 300° F. or previous cement grout as required.

(c) The surface of the pavement when complete is to be covered with one fourth inch coat consisting of clean aggregate, which shall be screened and thoroughly

SPECIFICATIONS FOR WOOD BLOCK PAVING. BROOKLYN.

(1) The wearing surface shall be composed of long leaf, all heart, yellow pine blocks, treated as hereinafter described. All blocks shall be of sound timber, free from bark, sapwood, loose or rotten knots, or other defects which shall be detrimental to the life of the block or interfere with its laying. No second growth timber will be allowed.

(2) The blocks are to be treated throughout with an antiseptic and water-proof mixture, at least fifty per cent of which shall be dead oil of coal tar, commonly called creosote oil. The remainder to be resin or some other similar and suitable water-proof material. All portions of each individual block shall be thoroughly treated with the mixture, and after treatment the specific gravity of the blocks shall be greater than that of the water.

(3) After treatment the blocks shall show such water-proof qualities that, after being dried in an oven at a temperature of one hundred degrees for a period of twenty-four hours, weighed, and then immersed in clear water for a period of twenty-four hours and weighed, the gain in weight shall not be greater than three per cent.

(4) In preparing the blocks to receive the creosote mixture, they shall be placed in an air tight cylinder in which dry heat is maintained and raised to a temperature of two hundred degrees F. for one hour for the purpose of expelling moisture; the heat shall then be increased until it reaches two hundred eighty-five degrees, this heat being maintained until the block is completely sterilized. Application of heat is then to be stopped and the temperature of the cylinder allowed to fall for one hour, or until the temperature has been reduced to 250 degrees. A vacuum shall then be applied until about twenty-six inches is reached, and while under this vacuum the creosote mixture shall be run into the cylinder at a temperature from 175 to 200 degrees, after

such hydraulic pressure of not less than 200 pounds per square inch shall be maintained until the individual blocks are grouted throughout.

(5) Upon the surface of the concrete foundation shall be spread a bed of cement mortar one half inch in thickness; this mortar surface shall be composed of a slow setting cement and clean, sharp sand, free from pebbles over one fourth inch in diameter, and mixed in the proportion of one part cement to four parts of sand. The mortar top shall be 'struck' to a true surface exactly parallel to the top of the finished pavement.

(6) The blocks shall not be less than two and one half inches wide, seven inches long and three inches deep, or three inches wide, eight inches long and four inches deep, uniform in depth or thickness. They shall be laid with the grain vertical and at such angle with the curb as the Engineer may direct. They shall be laid in parallel courses with the joints as tight as possible, each block being firmly imbedded in the mortar bed so as to form a true and even surface. The joints shall then be filled and kept filled with clean, fine sand.